(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 687 103 B1

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent:
29.09.1999 Bulletin 1999/39

(51) Int Cl.[6]: **H04N 1/60**

(21) Application number: **95303813.0**

(22) Date of filing: **05.06.1995**

(54) Color printer calibration with blended look up tables

Farbdruckerabgleich mit vermengten Nachschlagetabellen

Calibrage d'une imprimante en couleur avec des tables de consultation mélangées

(84) Designated Contracting States:
DE FR GB

(30) Priority: **06.06.1994 US 254629**

(43) Date of publication of application:
13.12.1995 Bulletin 1995/50

(73) Proprietor: **XEROX CORPORATION**
Rochester, New York 14644 (US)

(72) Inventors:
- **Rolleston, Robert J.**
  Penfield NY 14526 (US)
- **Maltz, Martin S.**
  Rochester NY 14618 (US)

(74) Representative: **Rackham, Stephen Neil et al**
GILL JENNINGS & EVERY,
Broadgate House,
7 Eldon Street
London EC2M 7LH (GB)

(56) References cited:

EP-A- 0 273 398	EP-A- 0 398 502
EP-A- 0 441 305	WO-A-91/02427
US-A- 5 262 833	US-A- 5 289 295

Printed by Jouve, 75001 PARIS (FR)

Description

[0001] The present invention is directed towards compiling look up tables representative of printer characteristics, to enable the conversion of colors defined in a first color space to colors defined in a printer color space, and more particularly to a method of blending or combining the characteristics represented by such tables.

[0002] With a view to providing a full understanding of the present invention, reference is made to the following patents: US-A-4,500,919 for its teachings of a color conversion system converting information from RGB to CMYK; US-A-4,275,413 for its teachings of tetrahedral interpolation between first and second color spaces; and US-A-2,790,844 disclosing the desirability of defining an image in a first standard color space prior to conversion of the image coordinates to a second printer based coordinate system. Reference is also made to the following articles: Po-Chieh Hung, "Tetrahedral Division Technique Applied to Colorimetric Calibration for Imaging Media", Annual Meeting IS&T, NJ, May, 1992, pp. 419-422; and Sigfredo I. Nin, et al., "Printing CIELAB Images on a CMYK Printer Using Tri-Linear Interpolation", SPIE Proceedings, Vol. 1670, 1992, pp. 316-324; and William J. Gordon et al., "Shepard's Method of 'Metric Interpolation' applied to Bivariate and Multivariate Interpolation", Mathematics of Computation, Vol. 32, No. 141, January 1978, pp. 253-264 and P. Lancaster et al., "Surfaces Generated by Moving Least Squares Methods", Mathematics of Computation, Vol. 32, No. 155, July 1981, pp.141-158; and Pekka Laihanen, "Colour Reproduction Theory Based on the Principles of Colour Science", Advances in Printing Science and Technology, W. H. Banks ed., Pentech Press, London, 1988, pp. 1-36; and Pekka Laihanen, "Optimization of Digital Color Reproduction on the Basis of Visual Assessment of Reproduced Images", Proceedings of the SID, Vol 30. No. 3, 1989, pp. 183-190.

[0003] The generation of color documents can be thought of as a two step process: first, the generation of the image by means of scanning an original document with a color image input terminal or scanner or, alternatively, creating a color image on a work station operated in accordance with a color image creation program; and secondly, printing of that image with a color printer in accordance with the colors defined by the scanner or computer generated image. Scanner output is commonly transformed to a color space of tristimulus values, i.e., RGB (red-green-blue). Commonly, these values are a linear transformation of the standard XYZ coordinates of CIE color space, or a corrected transform of those values. In the case of computer generated images, colors defined by the user at the user interface of a workstation can be defined initially in color space of tristimulus values. These colors are defined independently of any particular device, and accordingly reference is made to the information as being "device independent".

[0004] Printers commonly have an output which can be defined as existing in a color space called CMYK (cyan-magenta-yellow-key or black) which is uniquely defined for the printer by its capabilities and colorants. Printers operate by the addition of multiple layers of ink or colorant in layers to a page. The response of the printer tends to be relatively non-linear. These colors are defined for a particular device, and accordingly reference is made to the information as being "device dependent". Thus, while a printer receives information in a device independent color space, it must convert that information to print in a device dependent color space, which reflects the gamut or possible range of colors of the printer. Printers may print with colors beyond CMYK, for a variety of special purposes or to extend the device gamut.

[0005] The desirability of operating in a device independent color space with subsequent conversion to a device dependent color space is well known, as shown by US-A-4,500,919 and US-A-2,790,844, and US-A-4,275,413. There are many methods of conversion between color spaces, all of which begin with the measurement of printer response to certain input values. Commonly, a printer is driven with a set of input values reflecting color samples throughout the printer gamut, the color samples are printed in normal operation of the printer. As previously noted, most printers have non-linear response characteristics.

[0006] In US-A-4,275,413, the information derived is placed into look up tables, stored in a memory, perhaps ROM memory or RAM memory where the look up table relates input color space to output color space. The look up table is commonly a three dimensional table since color is defined with three variables. In RGB space, at a scanner or computer, space can be defined as three dimensional with black at the origin of a three dimensional coordinate system 0, 0, 0, and white at the maximum of a three dimensional coordinate system which an 8-bit system, would be located at 255, 255, 255. Each of the three axes radiating from the origin point therefore respectively define red, green, and blue. In the 8-bit system suggested, there will be, however, over 16 million possible colors (256^3). There are clearly too many values for a 1:1 mapping of RGB to CMY. Therefore, the look up tables consist of a set of values which could be said to be the intersections for comers of a set of cubes mounted on top of one another. Colors falling within each cubic volume can be interpolated from the measured values, through many methods including tri-linear interpolation, tetrahedral interpolation, polynomial interpolation, linear interpolation, and any other interpolation method depending on the desired accuracy of the result.

[0007] It would be very easy to index device dependent color values or specifications to device independent color specifications, but that is not the requirement. Instead, device independent specifications must be mapped to device dependent specifications. Several problems arise. Of course, the primary problem is that the printer response is not a linear response. A second problem is that the color space, and therefore the coordinates defined in the color space

must be maintained as a uniform grid for maximum efficiency of some interpolation methods.

[0008] Accordingly, a multi-dimensional look up table (LUT) may be constructed which puts device independent input values into a predictable grid pattern. One method of accomplishing this requirement is by an interpolation process which derives a value at a desired location as a function of all (or a significant set) of measured color values. This method of interpolation is known as Shepard's Method (see, for example "Shepard's Method of "Metric Interpolation' to Bivariate and Multivariate Interpolation" by W. Gordon and J. Wixom, Mathematics of Computation, Vol. 32, No. 141, January 1978, pp. 253-264). Shepard's Method suggests that a vector can be thought of as defining the difference between an asked-for color which was directed to a printer in the printed color. Then, for any other point in color space which is desired, that point can be thought of as a vector quantity, derived by averaging over the space all the vectors, each vector weighted by a function which decreases its effect on the vector as that vector is further and further away from the point coloring question. In one useful formula, each vector is weighted by a function of $1/_{d}{}^{4}$.

[0009] Alternatively the method of Po-Chieh Hung, "Colorimetric Calibration for Scanners and Media", SPIE, Vol. 1448, Camera and Input Scanner System, (1991), describes a method of inverse tetrahedral interpolation, to the same effect as the described Shepard's Method.

[0010] In one actual calibration test, it was noted that the weighted averaging technique produced a table which gave good color reproduction in one region of color space (the light colors), but not in another (the dark colors). The tetrahedral inversion technique was just the complement of this, i.e., it gave good color reproduction where the weighted average technique did not (the dark colors), and gave poorer color reproduction of colors where the weighted average technique gave good color reproduction (the light colors).

[0011] Similar to the above problem, it has been noted that often, after a change in process parameters due to time, change of materials, refilling toner, etc., a change in calibration is required only in a portion of the overall color gamut of a printer. Recalibration of the entire space is costly in terms of processing time. It would be desirable to only recalibrate a portion of the color space, or alternatively, to use the best portions of the color space mapping.

[0012] EP-A-398,502 discloses a method and system for providing closed loop colour control between a scanned colour image and the output of a colour printer. Errors in colour output of the copier/printer caused by events that occur between the input of the colour image scanner (10) and the output of the copier printer (18) driven thereby are continuously corrected. The techniques make use of a continuous comparison (40) of input test pattern data TP_{in}, from a small colour gamut or "patch" having only a selected few number of colour pixels therein with the output test pattern data, TP_{out}, from a colour printer (18) or copier to generate a colour correction conversion factor, H. Then, H is used to continuously update (42,86) an initial full scale look-up table which was initially prepared from a full scale colour gamut (Fig. 5). The initial look-up table has a colour conversion factor, F_{old}, and H is used to convert F_{old} to F_{new}, where $F_{new} = H \cdot F_{old}$. In this manner, H continuously corrects for undesirable changes in parameters used to generate the initial look-up table.

[0013] In accordance with this invention a method of calibrating a colour printer with blended look-up tables, the colour printer being responsive to printer signals to deposit printer colorants on a medium in accordance with printer signals received, including the steps of:

operating the colour printer with printer signals selected to cause the printer to print colour samples on the medium;
measuring the colour samples to determine a first colorimetric response of the printer to the printer signals;
using the first measured colorimetric response to generate a first mapping of colorimetric values to printer signals;
using the first measured colorimetric response or a subsequent measured colorimetric response to generate at least one additional mapping of colorimetric values to printer signals;
storing mapping data derived from the first and additional mappings in a colour conversion memory; and,
producing printer signals as a function of the mapping data to convert colour signals from a first colour space to the printer signals for producing a corresponding response at the colour printer;
is characterised in that the step of producing printer signals as a function of the first and additional mappings stored in the colour conversion memory does so in accordance with the function:

$$C,M,Y=A1(r,g,b)xLUT1(r,g,b)+A2(r,g,b)xLUT2$$

$$(r,g,b)+A3(r,g,b)xLUT3(r,g,b)+\ldots+AN$$

$$(r,g,b)xLUTN(r,g,b)$$

where C,M,Y is the printer signal produced as a function of the first and additional mappings stored in the

colour conversion memory, AN is a colour space location dependent weight and LUTN (r,g,b) is the first and additional mappings of colorimetric values to printer signals.

[0014] In accordance with another aspect of this invention a colour printer including a calibration system with blended look-up tables, the colour printer being responsive to printer signals directed thereto to deposit printer colorants on a medium in accordance with printer signals received, comprising:

means for generating printer signals selected to cause the printer to print colour samples on the medium;
means for measuring a first colorimetric response or the printer to the printer signals from the colour samples;
means for using the first measured colorimetric response to generate a mapping of colorimetric values to printer signals;
means for using the first measured colorimetric response or a subsequent measured colorimetric response to generate at least one additional mapping of colorimetric values to printer signals;
means for storing mapping data in a colour conversion memory, the mapping data being derived from the first and additional mappings; and
means for producing printer signals as a function of the mapping data, to convert colour definitions from a first colour space to printer signals suitable for producing a corresponding response at the colour printer;
is characterised in that the calibration system further includes means to generate and store colour space location dependent weighting signals;
multiplier means for multiplying the mapping and the additional mapping of the printer signals by their respective weighting signals;
an adder for adding the multiplied printer signals to provide an output response which is fed to the means for producing the printer signals as a function of the mapping data, the output response being a linear combination of the output responses of the separate mapping and additional mapping.

[0015] These and other aspects of the invention will become apparent from the following descriptions used to illustrate a preferred embodiment of the invention read in conjunction with the accompanying drawings, in which:-

Figures 1 and 2 together illustrate an overall system block diagram showing a colour printing system in which the present invention might find use; and
Figure 3 illustrates the blended mapping described.

[0016] Referring now to the drawings where the showings are for the purpose of describing an embodiment of the invention and not for limiting same, a basic system for carrying out the present invention is shown in Figure 1. In a system, a scanner 10, such as perhaps the colour scanner available in the Xerox 5775 digital colour copiers, which can be calibrated to produce a set of digital colorimetric or device independent data describing an original image 12, rendered in colours R_0, G_0,E_0, which, by definition, can be defined in terms of a colorimetric rgb space. Resulting from the scanning operation is a set of scanner image R_s, G_s, B_s, defined in device dependent scanner terms. Incorporated into the scanner or another processing path is a post-scanning processor 14, which provides correction of scanner image signals R_s, G_s, B_s to colorimetric terms, R_c, G_c, B_c, typically digital in nature. The values may be in terms of CIE colour space (rgb), or the L*a*b*, or luminance-chrominance space (LC_1C_2). A colour space transform, indicated by block 20, such as that described in US-A-4,275,413 to Sakamoto, is used to convert the device independent data to device dependent data. The output of color space transform 20 is the image defined in terms of a device dependent space, or printer colorant signals C_p, M_p, Y_p, K_p that will be used to drive a printer 30. In one possible example, the colorant signals represent the relative amounts of cyan, magenta, yellow, and black toners to be deposited over a given area in an electrophotographic printer, such as, again, Xerox 5775 digital color copier. The printed output image may be said to be defined in terms of R_p, G_p, B_p, which are hoped to have a relationship with R_o, G_o, B_o such that the printed output image has a color that is colorimetrically similar to the original image, although that similarity is ultimately dependent upon the gamut of the printing device.

[0017] With reference now to Figure 2, and color space transformation and color correction 20, initially, R_c, G_c, B_c color signals are directed to a lookup table and interpolation device 40, which provides a three dimensional look up arrangement in a device memory such as a RAM or other addressable memory device, which will meet speed and memory requirements for a particular device. Color signals R_c, G_c, B_c are processed to generate address entries to a table therein which stores a set of transform coefficients with which the signals R_c, G_c, B_c may be processed to convert them to C_x, M_x, Y_x colorant signals or any multi-dimensional output color space including but not limited to CMYK or spectral data. Values which are not mapped may be determined through interpolation. As described in US-A-5,305,119, entitled "Color Printer Calibration Architecture", black addition for under color removal and gray balance processing may also be combined into the color space transform element. Although these features are not required, they are

desirable and are illustrated herein. When we refer to colorimetric spaces, we are referring to spaces which are transforms of CIE XYZ space (1931). When we refer to device dependent space, we refer to a color space which is defined only in terms of operation of the device using it. While many color spaces have three dimensions, it is possible to have color spaces with less than three dimensions or more than three dimensions, and likewise, it is possible for printers to use less than three colorants or more than four colorants.

[0018] It will no doubt be recognized that there are many methods of providing a transform from device independent data to device dependent data, with US-A-4,275,413 describing one method, which itself can be varied. Once a conversion table is established, a method of interpolation referred to as tri-linear or cubic interpolation may also be used to calculate output values from the limited set of input values.

[0019] To create the table, a set of color patches are created, preferably including determined linearization and black addition. This is done by printing and measuring about 1000 to 4000 patches of printer colors distributed throughout the color space, i.e., a large set of printer driving signals are generated, in varying densities of combinations of C,M, Y,K, or other printer colors and used to drive the printer. The color of each patch is measured, using a spectraphotometer to determine color in terms of R_c,B_c,G_c. The measured colors of these patches are used to build a multi-dimensional look up table (LUT) relating R_c,B_c,G_c defined colors to $C_xM_xY_x$ defined colors. Conversions that do not include mapped and measured points may be interpolated or extrapolated. Reference is made to EP-A-000,000, corresponding to United States Patent Application No. 08/144,987 to Rolleston entitled, "Color Printer Calibration Test Pattern", filed October 29, 1993, which shows and describes a calibration test pattern for this purpose.

[0020] With reference again to Figure 1, a calibration image is conveniently stored in a device memory such as calibration ROM 60, RAM, floppy or the like, or generated on the fly with a predetermined generation function. Signals stored therein are directed to the printer under the control of printer controller 65. Densitometer, spectraphotometer or colorimetrically corrected scanner 70 is used to scan the calibration target and produce R_c, G_c, B_c signal values as a function of sensed density, representing the colors of each scanned patch. Interpatch correlation processor 80 reads the responses provided from densitometer 70 for each location in the calibration target and correlates the response with the input colorant signals, so that an $R_cG_cB_c$ to colorant mapping is generated.

[0021] The device independent values may be mapped to the device dependent space, perhaps in a manner described by Po-Chieh Hung, in "Colorimetric Calibration for Scanners and Media", SPIE, Vol. 1448, Camera and Input Scanner System, (1991).

[0022] With the look up table derived, it may be stored in LUT and interpolation 40, for use in converting device dependent values received from image creators to device independent printer signals.

[0023] In accordance with the invention, if for any reason a second set of mappings of colorimetric values to printer signals is generated, it immediately becomes apparent that one set may be better than the other set. More likely however, is that one set is better than the other set for only a portion of color space. Thus, a desire for optimum reproduction would require that both sets of data be used.

[0024] Accordingly, and with reference to Figure 3, within LUT and Interpolation 40 are multiple look up tables, including a weight table 100, and look up tables LUT1 ... LUTN, numbered 102. Conveniently, these tables are stored in RAM memory or the like. The tables are in a format that provides the colorimetic color description R_C, G_C, B_C as an index or input value to each table. Coefficient table 100 has as outputs coefficients A_1 ... A_N. Each coefficient A_1 ... A_N is derivable as a function of the position of the colorimetic color description in color space, and varies with the relative weight to be accorded to the LUT's relationship that region or portion of color space. In one embodiment, there is a set of coefficients A_1 . . . A_N corresponding to each table LUT1 . . . LUTN. Values are stored to coefficient table 100 and LUT1 . . .LUT from LUT processor 100. Coefficients stored to coefficient table 100 may also be operator or user generated and input to coefficient table 100 from a user interface.

[0025] LUT1 . . .LUTN are tables derived through the processes described above for the generation of first color space to second color space conversion. They are also in a format that provides the colorimetic color description R_C, G_C, B_C as an index or input value to each table, but provide, for example, output CMYK signals. The signals are from LUT output respectively to multipliers 120_1 ... 120_N which have as a second input a corresponding coefficient A1...AN from Table 100. The output of multipliers 120_1...120_N is directed to an adder or accumulator 130 which actually adds the results together and directs its output to another area in memory, LUT_{NEW} 134. From this area in memory, interpolator 140 can receive the stored information to produce its color conversion values. Interpolator 140, using for example trilinear or tetrahedral interpolation (as taught for example in US-A-4,275,413) uses the stored LUT values to derive interpolated output values. (Figure 3 shows block 40 from Figure 1, labeled LUT AND INTERPOLATION, and therefore should include the tetrahedral or trilinear interpolation function, which is represented by interpolator 140.)

[0026] It can therefore be seen that the plural table blending function is characterized by

$$LUT_{NEW}(r,g,b)= A1(r,g,b) \times LUT1(r,g,b) + A2(r,g,b) \times LUT2(r,g,b) + A3(r,g,b)$$

$$\times \mathrm{LUT3}(r,g,b) + \ldots + \mathrm{AN}(r,g,b) \times \mathrm{LUTN}(r,g,b)$$

such that

$$\mathrm{A1}(r,g,b) + \mathrm{A2}(r,g,b) + \mathrm{A3}(r,g,b) + \ldots + \mathrm{AN}(r,g,b) = 1$$

at each location in color space.

[0027] It is interesting to note that the case of only two tables, LUT1 and LUT 2 (which is expected to be a common case), can be addressed in a special manner, since if weight A1 = A is accorded to LUT1, the weight A2 for LUT 2 is equal 1-A, and accordingly need not be stored independently. The special case of two LUT's can be addressed as:

$$\mathrm{LUT}_{\mathrm{NEW}}(r,g,b) = \mathrm{A}(r,g,b) \times \mathrm{LUT1}(r,g,b) + [1-\mathrm{A}(r,g,b)] \times \mathrm{LUT2}([[(r,g,b)$$

where LUT1() and LUT2() are the values of the first and second LUT's at some location (i.e. r, g, b) in the table, and A() is a function of the table location such that 0< = A < = 1. Of course, this result can be generalized to include N tables with N-1 weights.

[0028] In considering the function of position, it is useful to note that the function need not be a linear combination of LUT's. A particularly valuable function may represent use of only a single LUT at any point in space. Thus, within the area best characterized by LUT N, $A_{N=1}$, while all other LUT's have a value of A = 0.

[0029] The embodiment described has been illustrated as generating a new LUT, named $\mathrm{LUT}_{\mathrm{NEW}}$. However, it is within the scope of the invention to generate blended values from LUT1 ... LUTN on the fly, without storage or creation of a new LUT. Thus, the output of adder 130 would be directed immediately to interpolator 140, for each value of $R_C G_C B_C$ which is directed to coefficient table 100 and LUT table 102.

[0030] It is worth noting that the blending can be performed in any color space or coordinate system, and that the idea is not limited to using a linear combination of the preliminary LUTs. The novel aspect of this invention is the ability to combine several different LUTs into a single LUT. This technique has been reduced to practice, and in the example sighted above, the weights were set such that A = 1 at R, G, B C,M,Y and W (i.e., all colors including white), and A = 0 at K (black). Intermediate values of A were calculated by interpolation within this cube. LUT1 was the LUT which resulted from using a weighted average, and LUT2 was obtained by using tetrahedral inversion.

[0031] It will no doubt be appreciated that while we have shown the use of the invention in the conversion of a device independent color space to a device dependent color space, the invention applies equally as well to conversions to any transformation from a first space to a second space, irrespective of the nature of the space as device dependent or not.

[0032] It will no doubt be appreciated that the present invention can be accomplished through application software accomplishing the described functions, though a hardware circuit, which will probably provide optimum speed, or through some combination of software and hardware.

Claims

1. A method of calibrating a colour printer with blended look-up tables, the colour printer being responsive to printer signals to deposit printer colorants on a medium in accordance with printer signals received, including the steps of:

   operating the colour printer with printer signals selected to cause the printer to print colour samples on the medium;
   measuring the colour samples to determine a first colorimetric response of the printer to the printer signals;
   using the first measured colorimetric response to generate a first mapping of colorimetric values to printer signals;
   using the first measured colorimetric response or a subsequent measured colorimetric response to generate at least one additional mapping of colorimetric values to printer signals;
   storing mapping data derived from the first and additional mappings in a colour conversion memory; and,
   producing printer signals as a function of the mapping data to convert colour signals from a first colour space to the printer signals for producing a corresponding response at the colour printer;
   characterised in that the step of producing printer signals as a function of the first and additional mappings stored in the colour conversion memory does so in accordance with the function:

$$C,M,Y=Al(r,g,b)xLUT1(r,g,b)+A2(r,g,b)xLUT2(r,g,b)+A3(r,g,b)xLUT3(r,g,b)+...+AN(r,g,b)xLUTN(r,g,b)$$

where C,M,Y is the printer signal produced as a function of the first and additional mappings stored in the colour conversion memory, AN is a colour space location dependent weight and LUTN(r,g,b) is the first and additional mappings of colorimetric values to printer signals.

2. The method of claim 1, wherein said mapping data further comprises (A) the first and additional mappings, or (B) a colour conversion mapping, the method including the step of generating a colour conversion mapping as a function of the first and additional mappings.

3. A colour printer including a calibration system with blended look-up tables, the colour printer being responsive to printer signals (C_p, M_p, Y_p, K_p) directed thereto to deposit printer colorants on a medium in accordance with printer signals received, comprising:

means (60,65) for generating printer signals selected to cause the printer to print colour samples on the medium;
means (70) for measuring a first colorimetric response or the printer to the printer signals from the colour samples;
means for using the first measured colorimetric response to generate a mapping (102) of colorimetric values to printer signals;
means for using the first measured colorimetric response or a subsequent measured colorimetric response to generate at least one additional mapping (102) of colorimetric values to printer signals;
means for storing mapping data in a colour conversion memory (134), the mapping data being derived from the first and additional mappings (102); and
means (140) for producing printer signals as a function of the mapping data, to convert colour definitions from a first colour space to printer signals suitable for producing a corresponding response at the colour printer;
characterised in that the calibration system further includes means (100) to generate and store colour space location dependent weighting signals;
multiplier means (120) for multiplying the mapping (102) and the additional mapping (102) of the printer signals by their respective weighting signals;
an adder (130) for adding the multiplied printer signals to provide an output response which is fed to the means (140) for producing the printer signals as a function of the mapping data, the output response being a linear combination of the output responses of the separate mapping (102) and additional mapping (102).

4. A colour printer according to claim 3, wherein the means (140) for producing printer signals as a function of the mapping data does so in accordance with the function:

$$C,M,Y=A1(r,g,b)xLUT1(r,g,b)+A2(r,g,b)xLUT2(r,g,b)+A3(r,g,b)xLUT3(r,g,b)+...+AN(r,g,b)xLUTN(r,g,b)$$

where C,M,Y is the printer signal produced as a function of the first and additional mappings stored in the colour conversion memory, AN is a colour space location dependent weight and LUTN(r,g,b) is the first and additional mappings of colorimetric values to printer signals.

5. A colour printer according to claim 3 or 4, wherein the mapping data comprises (A) the first and additional mappings, or (B) a colour conversion mapping, the printer further including means for combining at least the first measured colorimetric response and any subsequent measured colorimetric response to produce the colour conversion mapping.

6. A method or device as described in any of the preceding claims, wherein said colorimetric signals are red, green and blue signals.

7. A method or device as described in any of the preceding claims, wherein said printer signals correspond to (A) printing cyan, magenta and yellow colorants, (B) printing cyan, magenta, yellow and black colorants, (C) printing cyan, magenta, yellow and at least one additional different non-black colorant or (D) printing cyan, magenta, yellow, black and at least one additional different colorant.

8. A method or device as described in any of the preceding claims, wherein

$$A1 + A2 + A3 \ldots + AN = 1.$$

9. A method or device as described in any of the preceding claims, where a single member of the set {A1,A2+A3... +AN} is equal to 1, and the remaining number or members of the set are equal to 0 at any location in location in colour space.

10. A method of calibrating a color printer using blended look up tables, the colour printer being responsive to printer signals to deposit printer colorants on a medium in accordance with printer signals received, including the steps of:

producing a calibration print as a printer response sample;
deriving a first mapping relating colorimetric values to printer response;
deriving at least one additional mapping relating colorimetric values to printer response;
generating a colour conversion mapping as a function of the first and additional mappings, wherein the colour conversion mapping is performed according to the function C,M,Y, = A1(r,g,b) x LUT1(r,g,b) + A2(r,g,b) x LUT2 (r,g,b) + A3(r,g,b) x LUT3(r,g,b) + ... + AN(r,g,b) x LUTN(r,g,b) where C,M,Y is the printer signal produced as a function of the first and additional mappings stored in the colour conversion memory, AN is a colour space location dependent weight and LUTN is the first and additional mappings of colorimetric values to printer signals;
storing said colour conversion mapping in a colour conversion memory; and,
operating the calibrated printer with the colour conversion mapping to convert colorimetric values received to printer signals.

Patentansprüche

1. Verfahren zur Kalibrierung eines Farbdruckers mit vermengten Nachschlagetabellen, wobei der Farbdrucker auf Druckersignale reagiert, um Druckerfarbmittel auf einem Medium gemäß den erhaltenen Druckersignalen abzusetzen, das die Schritte enthält:

Betreiben des Farbdruckers mit Druckersignalen, die ausgewählt sind, daß der Drucker Farbproben auf das Medium druckt;

Messen der Farbproben, um eine erste kolorimetrische Reaktion des Druckers auf die Druckersignale zu bestimmen;

Verwenden der ersten gemessenen kolorimetrischen Reaktion, um eine erste Abbildung kolorimetrischer Werte auf Druckersignale zu erzeugen;

Verwenden der ersten gemessenen kolorimetrischen Reaktion oder einer nachfolgend gemessenen kolorimetrischen Reaktion, um zumindest eine zusätzliche Abbildung kolorimetrischer Werte auf Druckersignale zu erzeugen;

Speichern von Abbildungsdaten, die von der ersten und der zusätzlichen Abbildung erzeugt worden sind, in einem Farbumwandlungsspeicher;

Erzeugen von Druckersignalen als Funktion der Abbildungsdaten, um Farbsignale von einem ersten Farbraum in Druckersignale umzuwandeln, um eine entsprechende Reaktion bei dem Farbdrucker zu erzeugen;

dadurch gekennzeichnet, daß der Schritt, Druckersignale als Funktion der ersten und zusätzlichen Abbildungsdaten zu erzeugen, die in dem Farbumwandlungsspeicher gespeichert sind, dies gemäß der Funktion vornimmt:

$$C,M,Y = A1(r,g,b) \times LUT1\ (r,g,b) + A2(r,g,b) \times LUT2(r,g,b) + A3(r,g,b) \times$$

$$LUT3(r,g,b) + .. + AN(r,g,b) \times LUTN(r,g,b)$$

worin C,M,Y das Druckersignal ist, das als Funktion der ersten und der zusätzlichen in dem Farbumwandlungsspeicher gespeicherten Abbildung erzeugt wird, AN ein von dem Farbraumort abhängiges Gewicht ist und LUT(r,g,b) die erste und zusätzliche Abbildung der kolorimetrischen Werte auf Druckersignale ist.

2. Das Verfahren des Anspruchs 1, wobei die genannten Abbildungsdaten des weiteren (A) die erste und die zusätzliche Abbildung oder (B) eine Farbumwandlungsabbildung umfassen, und das Verfahren den Schritt der Erzeugung einer Farbumwandlungsabbildung als Funktion der ersten und der zusätzlichen Abbildung einschließt.

3. Ein Farbdrucker, der ein Kalibrierungssystem mit vermengten Nachschlagetabellen einschließt, wobei der Farbdrucker auf Druckersignale (C_p, M_p, Y_p, K_p) reagiert, die dorthin gerichtet sind, um Druckerfarbmittel auf einem Medium gemäß den erhaltenen Druckersignalen abzusetzen, umfassend:

eine Einrichtung (60, 65) zur Erzeugung von Druckersignalen, die ausgewählt sind, damit der Drucker Farbproben auf das Medium druckt,;

eine Einrichtung (70) zum Messen einer ersten kolorimetrischen Reaktion des Druckers auf Druckersignale von den Farbproben;

eine Einrichtung zum Verwenden der ersten gemessenen kolorimetrischen Reaktion, um eine Abbildung (102) kolorimetrischer Werte auf Druckersignale zu erzeugen;

eine Einrichtung zum Verwenden der ersten gemessenen kolorimetrischen Reaktion oder einer nachfolgend gemessenen kolorimetrischen Reaktion, um zumindest eine zusätzliche Abbildung (102) kolorimetrischer Werte auf Druckersignale zu erzeugen;

eine Einrichtung zum Speichern von Abbildungsdaten in einem Farbumwandlungsspeicher (134), wobei die Abbildungsdaten von der ersten und der zusätzlichen Abbildung (102) abgeleitet werden;

eine Einrichtung (140) zum Erzeugen von Druckersignalen als Funktion der Abbildungsdaten, um Farbdefinitonen von einem ersten Farbraum in Druckersignale umzuwandeln, die zur Erzeugung einer entsprechenden Reaktion bei dem Farbdrucker geeignet sind;

dadurch gekennzeichnet, daß das Kalibrierungssystem des weiteren eine Einrichtung (100) beinhaltet, von dem Farbraumort abhängige Gewichtssignale zu erzeugen und zu speichern;

eine Multiplikationseinrichtung (120) zur Multiplikation der Abbildung (102) und der zusätzlichen Abbildung (102) der Druckersignale mit ihren entsprechenden Gewichtssignalen;

einen Addierer (130) zur Addition der multiplizierten Druckersignale, um eine Ausgangsreaktion zu erzeugen, die der Einrichtung (140) zur Erzeugung von Druckersignalen als Funktion der Abbildungsdaten zugeführt wird, wobei die Ausgangsreaktion eine lineare Kombination der Ausgangsreaktionen der getrennten Abbildung (102) und der zusätzlichen Abbildung (102) ist.

4. Ein Farbdrucker gemäß Anspruch 3, wobei die Einrichtung (140) zur Erzeugung von Druckersignalen als Funktion der Abbildungsdaten dies gemäß der Funktion vornimmt:

$$C,M,Y = A1(r,g,b) \times LUT1\ (r,g,b) + A2(r,g,b) \times LUT2(r,g,b) + A3(r,g,b) \times$$

LUT3(r,g,b)+.. + AN(r,g,b) x LUTN(r,g,b)

worin C,M,Y das Druckersignal ist, das als Funktion der ersten und der zusätzlichen in dem Farbumwandlungsspeicher gespeicherten Abbildung erzeugt wird, AN ein von dem Farbraumort abhängiges Gewicht ist und LUT(r,g,b) die erste und zusätzliche Abbildung der kolorimetrischen Werte auf Druckersignale ist.

5. Ein Farbdrucker gemäß Anspruch 3 oder 4, wobei die Abbildungsdaten (A) die erste und die zusätzliche Abbildung oder (B) eine Farbumwandlungsabbildung umfassen, wobei der Drucker des weiteren eine Einrichtung zur Kombination zumindest der ersten gemessenen kolorimetrischen Reaktion und irgendeiner nachfolgend gemessenen kolorimetrischen Reaktion enthält, um die Farbumwandlungsabbildung zu erzeugen.

6. Ein Verfahren oder eine Einrichtung, wie in irgendeinem der vorhergehenden Ansprüche beschrieben, wobei die kolorimetrischen Signale Rot-, Grün- und Blausignale sind.

7. Ein Verfahren oder eine Einrichtung, wie in irgendeinem der vorhergehenden Ansprüche beschrieben, wobei die Druckersignale (A) dem Drucken von Zyan-, Magenta- und gelben Farbmitteln, (B) dem Drucken von Zyan-, Magenta-, gelbem und schwarzem Farbmittel, (C) dem Drucken von Zyan-, Magenta-, gelbem und wenigstens einem zusätzlichen von schwarz verschiedenen Farbmittel oder (D) dem Drucken von Zyan-, Magenta-, gelbem, schwarzem und zumindest einem zusätzlichen verschiedenen Farbmittel entspricht.

8. Ein Verfahren oder eine Einrichtung, wie in irgendeinem der vorhergehenden Ansprüche beschrieben, wobei

$$A1 + A2 + A3 + AN = 1.$$

9. Ein Verfahren oder eine Einrichtung, wie in irgendeinem der vorhergehenden Ansprüche beschrieben, wobei ein einzelnes Element der Gruppe (A1, A2, A3 +AN) gleich 1 ist, und die restliche Anzahl oder Elemente der Gruppe gleich 0 an jedem Ort in dem Farbraum ist.

10. Ein Verfahren zur Kalibrierung eines Farbdruckers, der vermengte Nachschlagetabellen verwendet, wobei der Farbdrucker auf Druckersignale reagiert, um Druckerfarbmittel auf einem Medium gemäß erhaltenen Druckersignalen abzusetzen, das die Schritte enthält:

Erzeugen eines Kalibrierungsdrucks als Druckerreaktionsprobe;

Ableiten einer ersten Abbildung, die kolorimetrische Werte zur Druckerreaktion in Beziehung setzt;

Ableiten zumindest einer zusätzlichen Abbildung, die kolorimetrische Werte zur Druckerreaktion in Beziehung setzt;

Erzeugen einer Farbumwandlungsabbildung als Funktion der ersten und der zusätzlichen Abbildung, wobei die Farbumwandlungsabbildung ausgeführt wird gemäß der Funktion

C; M, Y =A1 (r,g,b) × LUT1 (r,g,b) A2(r,g,b) x LUT2(r,g,b) + A3(r,g,b) x

LUT3(r,g,b)+.. + AN(r,g,b) x LUT(r,g,b)

worin C,M,Y das Druckersignal ist, das als Funktion der ersten und der zusätzlichen in dem Farbumwandlungsspeicher gespeicherten Abbildung erzeugt wird, AN ein von dem Farbraumort abhängiges Gewicht ist und LUT(r,g,b) die erste und zusätzliche Abbildung der kolorimetrischen Werte auf die Druckersignale ist;

Speichern der genannten Farbumwandlungsabbildung in einem Farbumwandlungsspeicher;

Betreiben des kalibrierten Druckers mit der Farbumwandlungsabbildung, um erhaltene kolorimetrische Werte in Druckersignale umzuwandeln.

Revendications

1. Procédé de calibrage d'une imprimante en couleurs à l'aide de tables de consultation mélangées, l'imprimante en couleurs étant sensible à des signaux d'imprimante pour déposer des colorants d'imprimante sur un support conformément à des signaux d'imprimante reçus, incluant les étapes consistant :

   à commander l'imprimante en couleurs à l'aide de signaux d'imprimante sélectionnés pour amener l'imprimante à imprimer des échantillons de couleurs sur le support ;
   à mesurer les échantillons de couleurs afin de déterminer une première réponse colorimétrique de l'imprimante aux signaux d'imprimante ;
   à utiliser la première réponse colorimétrique mesurée afin de générer un premier mappage des valeurs colorimétriques aux signaux d'imprimante ;
   à utiliser la première réponse colorimétrique mesurée ou bien une réponse colorimétrique mesurée subséquente afin de générer au moins un mappage additionnel des valeurs colorimétriques aux signaux d'imprimante ;
   à mémoriser les données de mappage dérivées du premier mappage et du mappage additionnel, dans une mémoire de conversion de couleurs ; et,
   à produire des signaux d'imprimante en fonction des données de mappage de manière à convertir des signaux de couleurs d'un premier espace de couleurs en signaux d'imprimante pour produire une réponse correspondante à l'imprimante en couleurs ;
   caractérisé en ce que l'étape consistant à produire les signaux d'imprimante en fonction du premier mappage et du mappage additionnel mémorisés dans la mémoire de conversion de couleurs y parviennent conformément à la fonction :

$$C,M,Y = A1\ (r,g,b) \times LUT1\ (r,g,b) + A2\ (r,g,b) \times LUT2\ (r,g,b) + A3\ (r,g,b) \times LUT3\ (r,g,b) + \ldots + AN\ (r,g,b) \times LUTN\ (r,g,b)$$

   où C,M,Y est le signal d'imprimante produit en fonction du premier mappage et du mappage additionnel mémorisés dans la mémoire de conversion de couleurs, AN est une pondération dépendant de l'emplacement dans l'espace de couleurs et LUTN (r,g,b) est le premier mappage et le mappage additionnel des valeurs colorimétriques aux signaux d'imprimante.

2. Procédé selon la revendication 1, dans lequel lesdites données de conversion de mappage comprennent, en outre, (A) le premier mappage et le mappage additionnel, ou bien (B) un mappage de conversion de couleurs, le procédé incluant l'étape consistant à générer un mappage de conversion de couleurs en fonction du premier mappage et du mappage additionnel.

3. Imprimante en couleurs incluant un système de calibrage à l'aide de tables de consultation mélangées, l'imprimante en couleurs étant sensible à des signaux d'imprimante (C_P, M_P, Y_P, K_P) qui sont dirigés sur elle afin de déposer des colorants d'imprimante sur un support conformément à des signaux d'imprimante reçus, comprenant :

   des moyens (60, 65) destinés à générer des signaux d'imprimante sélectionnés pour amener l'imprimante à imprimer des échantillons de couleurs sur le support ;
   des moyens (70) destinés à mesurer une première réponse colorimétrique de l'imprimante aux signaux d'imprimante à partir des échantillons de couleurs ;
   des moyens destinés à utiliser la première réponse colorimétrique mesurée afin de générer un mappage (102) des valeurs colorimétriques aux signaux d'imprimante ;
   des moyens destinés à utiliser la première réponse colorimétrique mesurée ou bien une réponse colorimétrique mesurée subséquente afin de générer au moins un mappage additionnel (102) de valeurs colorimétriques aux signaux d'imprimante ;
   des moyens destinés à mémoriser des données de mappage dans une mémoire de conversion de couleurs (134), les données de mappage étant dérivées du premier mappage et du mappage additionnel (102) ; et
   des moyens (140) destinés à produire des signaux d'imprimante en fonction des données de mappage, de manière à convertir les définitions de couleurs à partir d'un premier espace de couleurs en des signaux d'im-

primante appropriés pour produire une réponse correspondante à l'imprimante en couleurs ;
caractérisée en ce que le système de calibrage inclut, en outre, des moyens (100) destinés à générer et à mémoriser des signaux de pondération dépendant de l'emplacement dans l'espace de couleurs ;
des moyens multiplicateurs (120) destinés à multiplier le mappage (102) et le mappage additionnel (102) des signaux d'imprimante par leurs signaux de pondération respectifs ;
un additionneur (130) destiné à additionner les signaux d'imprimante multipliés afin de délivrer une réponse de sortie qui est entrée dans les moyens (140) destinés à produire les signaux d'imprimante en fonction des données de mappage, la réponse de sortie étant une combinaison linéaire des réponses de sortie du mappage et du mappage additionnel (102) séparés.

4. Imprimante en couleurs selon la revendication 3, dans laquelle les moyens (140) destinés à produire les signaux d'imprimante en fonction des données de mappage y parviennent conformément à la fonction :

$$C,M,Y = A1\ (r,g,b) \times LUT1\ (r,g,b) + A2\ (r,g,b) \times LUT2\ (r,g,b) + A3\ (r,g,b) \times LUT3\ (r,g,b) + \ldots + AN\ (r,g,b) \times LUTN\ (r,g,b)$$

où C,M,Y est le signal d'imprimante produit en fonction du premier mappage et du mappage additionnel mémorisés dans la mémoire de conversion de couleurs, AN est une pondération dépendant de l'emplacement dans l'espace de couleurs et LUTN (r,g,b) est le premier mappage et le mappage additionnel des valeurs colorimétriques aux signaux d'imprimante.

5. Imprimante en couleurs selon la revendication 3 ou 4, dans laquelle les données de mappage comprennent (A) le premier mappage et le mappage additionnel, ou bien (B) un mappage de conversion de couleurs, l'imprimante incluant, en outre, des moyens destinés à combiner au moins la première réponse colorimétrique mesurée et une toute réponse colorimétrique mesurée subséquente de manière à produire le mappage de conversion de couleurs.

6. Procédé ou appareil selon l'une quelconque des revendications précédentes, dans lequel lesdits signaux colorimétriques sont les signaux de rouge, de vert et de bleu.

7. Procédé ou appareil selon l'une quelconque des revendications précédentes, dans lequel lesdits signaux d'imprimante correspondent (A) à l'impression de colorants de cyanure, de magenta et de jaune, (B) à l'impression de colorants de cyanure, de magenta, de jaune et de noir, (C) à l'impression de colorants de cyanure, de magenta, de jaune et au moins d'un colorant additionnel différent et non noir ou (D) à l'impression de colorants de cyanure, de magenta, de jaune, de noir et au moins d'un colorant additionnel différent.

8. Procédé ou appareil selon l'une quelconque des revendications précédentes, dans lequel

$$A_1 + A_2 + A_3 \ldots + A_N = 1.$$

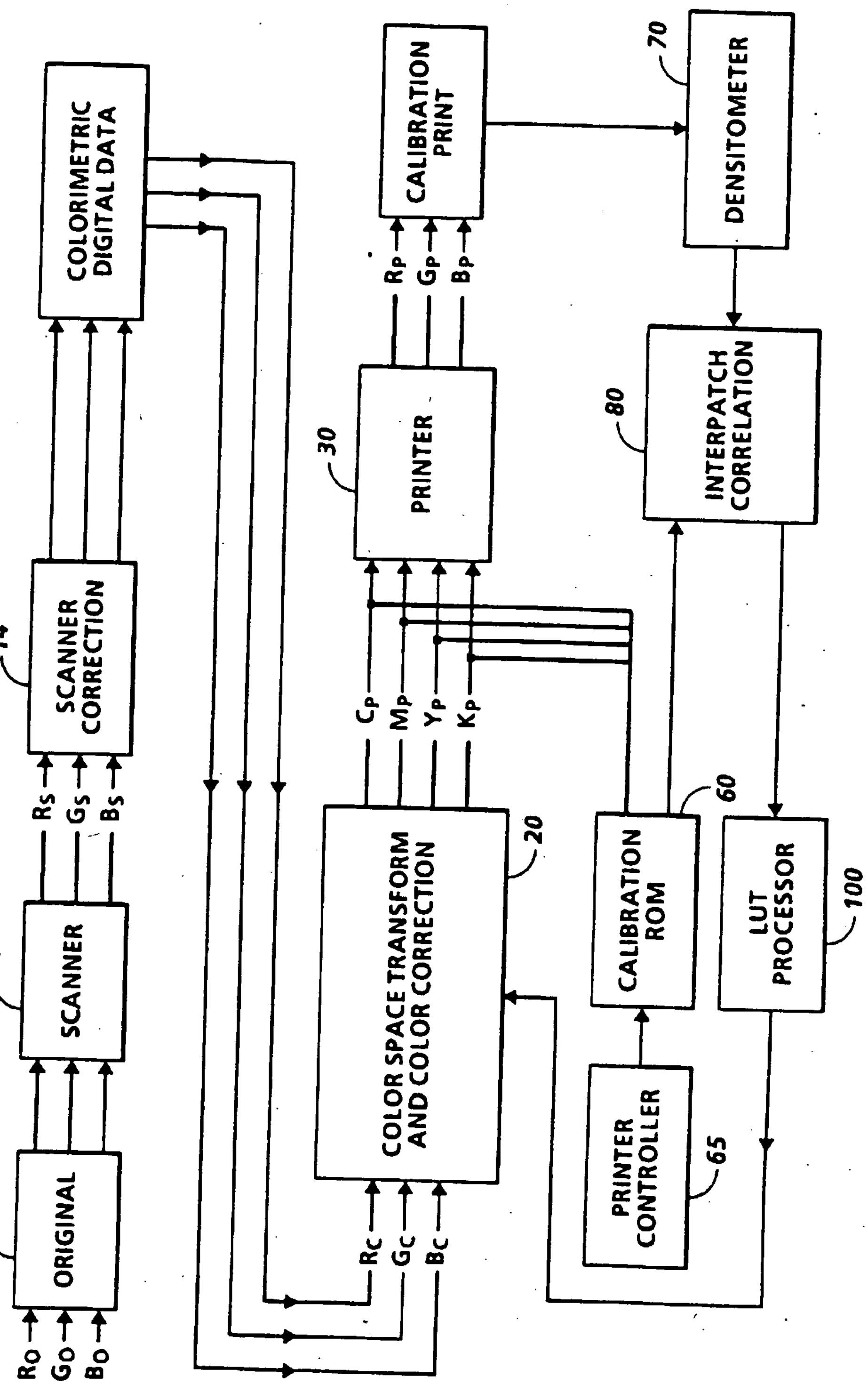
9. Procédé ou appareil selon l'une quelconque des revendications précédentes, dans lequel un seul élément de l'ensemble $\{A_1, A_2 + A_3 \ldots + A_N\}$ est égal à 1, et les éléments restants de l'ensemble sont égaux à 0 en tout point de l'espace de couleurs.

10. Procédé de calibrage d'une imprimante en couleurs à l'aide de tables de consultation mélangées, l'imprimante en couleurs étant sensible à des signaux d'imprimante pour déposer des colorants d'imprimante sur un support conformément à des signaux d'imprimante reçus, incluant les étapes consistant :

à produire une impression de calibrage à titre d'échantillon de réponse d'imprimante ;
à dériver un premier mappage reliant les valeurs colorimétriques à la réponse de l'imprimante ;
à dériver au moins un mappage additionnel reliant les valeurs colorimétriques à la réponse de l'imprimante ;
à générer un mappage de conversion de couleurs en fonction du premier mappage et du mappage additionnel, dans lequel le mappage de conversion de couleurs s'accomplit conformément à la fonction :

$$C,M,Y = A1\,(r,g,b) \times LUT1\,(r,g,b) + A2\,(r,g,b) \times LUT2\,(r,g,b) + A3\,(r,g,b) \times LUT3\,(r,g,b) + \ldots + AN\,(r,g,b) \times LUTN\,(r,g,b)$$

où C,M,Y est le signal d'imprimante produit en fonction du premier mappage et du mappage additionnel mémorisés dans la mémoire de conversion de couleurs, AN est une pondération dépendant de l'emplacement dans l'espace de couleurs et LUTN (r,g,b) est le premier mappage et le mappage additionnel des valeurs colorimétriques aux signaux d'imprimante ;
à mémoriser ledit mappage de conversion de couleurs dans une mémoire de conversion de couleurs ; et
à faire fonctionner l'imprimante calibrée à l'aide du mappage de çonversion de couleurs de manière à convertir les valeurs colorimétriques en signaux d'imprimante.



ORIGINAL
SCANNER
SCANNER CORRECTION
COLORIMETRIC DIGITAL DATA
COLOR SPACE TRANSFORM AND COLOR CORRECTION
PRINTER
CALIBRATION PRINT
DENSITOMETER
INTERPATCH CORRELATION
CALIBRATION ROM
LUT PROCESSOR
PRINTER CONTROLLER
12
10
14
20
30
60
65
70
80
100

FIG. 1

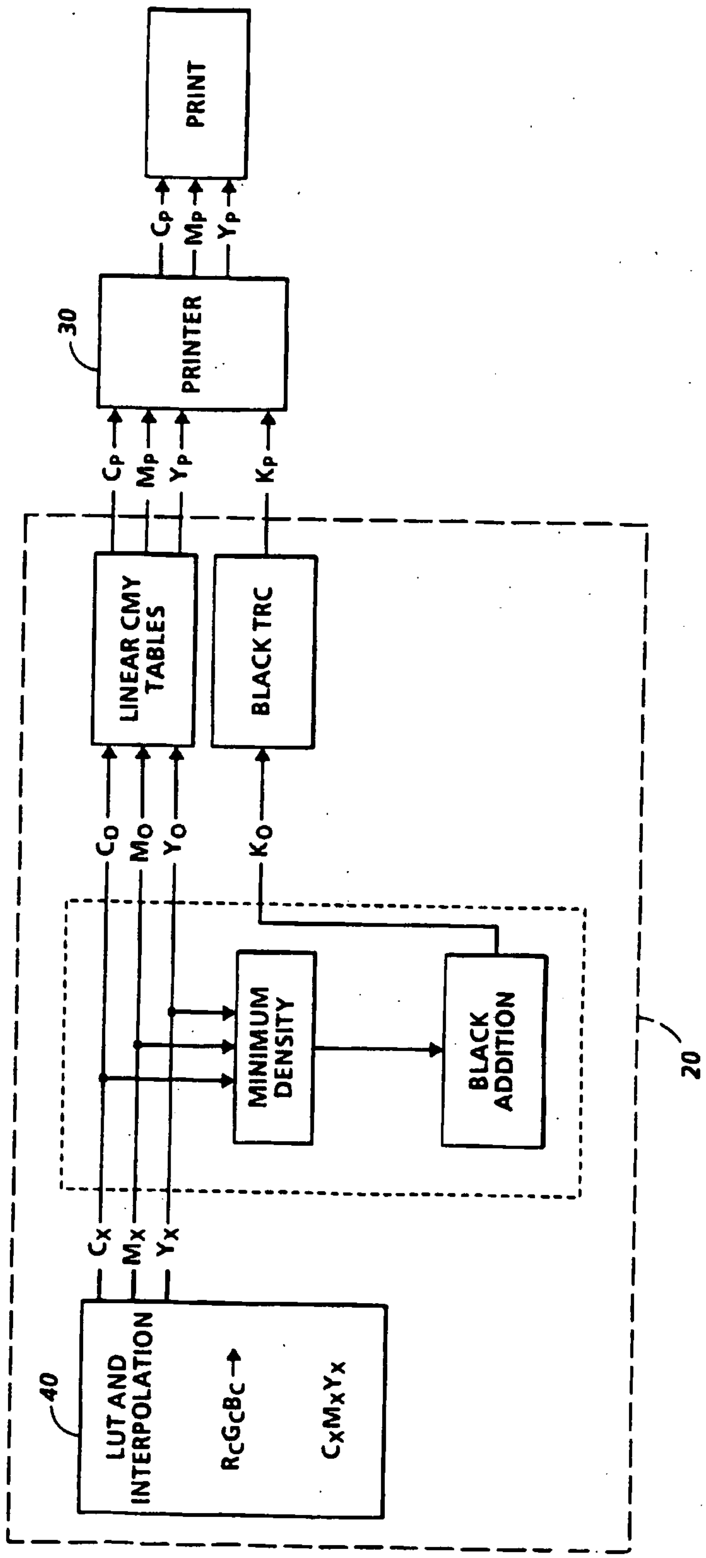

PRINT
PRINTER
30
LINEAR CMY TABLES
BLACK TRC
MINIMUM DENSITY
BLACK ADDITION
LUT AND INTERPOLATION
$R_CG_CB_C \rightarrow$
$C_XM_XY_X$
40
20
C_X
M_X
Y_X
C_O
M_O
Y_O
K_O
C_P
M_P
Y_P
K_P

FIG. 2

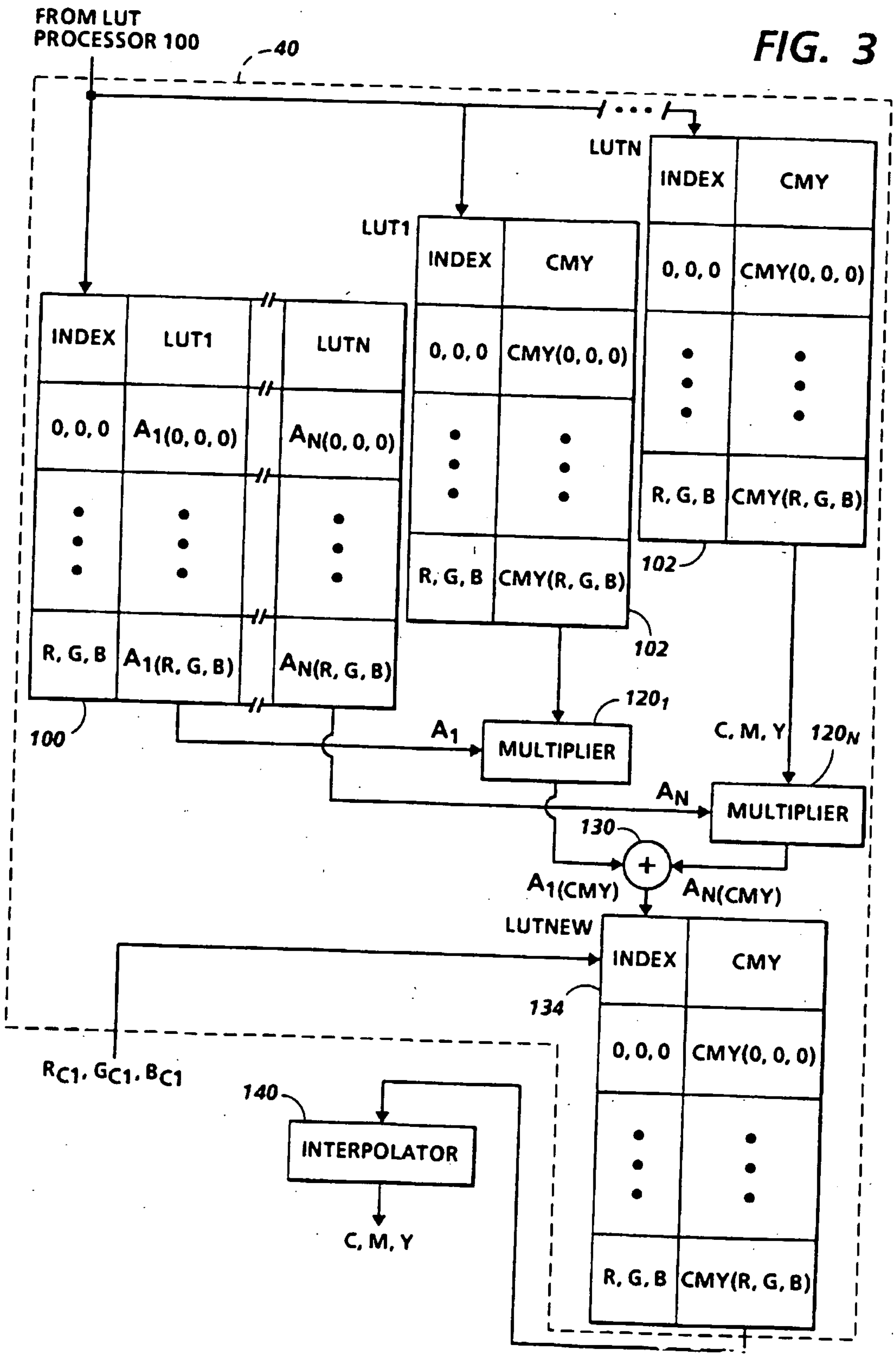

FROM LUT
PROCESSOR 100
40
LUTN
INDEX
CMY
0, 0, 0
CMY(0, 0, 0)
R, G, B
CMY(R, G, B)
102
LUT1
INDEX
CMY
0, 0, 0
CMY(0, 0, 0)
R, G, B
CMY(R, G, B)
102
INDEX
LUT1
LUTN
0, 0, 0
A1(0, 0, 0)
AN(0, 0, 0)
R, G, B
A1(R, G, B)
AN(R, G, B)
100
A1
MULTIPLIER
120₁
C, M, Y
120N
AN
MULTIPLIER
130
A1(CMY)
AN(CMY)
LUTNEW
INDEX
CMY
134
0, 0, 0
CMY(0, 0, 0)
R, G, B
CMY(R, G, B)
RC1, GC1, BC1
140
INTERPOLATOR
C, M, Y

FIG. 3